REMARKS

Claims 19-72 are pending in the application. Claims 19-45 have been allowed. Applicant has added new claims 46-72 in this amendment. In adding the new claims, Applicant has added no new matter. Support for the amendments above can be found in the specification and claims of the application as filed.

Conclusion

Applicant respectfully submits that all pending claims, 1-72, are allowable. Applicant respectfully solicits the issuance of a Notice of Allowance for all claims.

Should the Examiner have any comments, questions or suggestions of a nature necessary to expedite the prosecution of the application, he is courteously requested to telephone the undersigned at the number listed below.

Respectfully submitted,

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SPECIFICATION WITH MARKINGS TO SHOW CHANGES/AMENDMENTS MADE

In accordance with 37 CFR 1.121(b), the following version of the specification as rewritten by the foregoing amendments, shows the changes made relative to previous versions of the specification.

The paragraph beginning on page 3, line 15 has been amended as follows:

Further, by reacting to remote forces present on a slave device, the prior art devices lack the capability of creating a three-dimensional tactile virtual reality environment whereby a user's actions and reactions are related to a simulated world such as simulations of driving or flying functions, simulation of molecular force interactions, or simulations of surgical procedures. U.S. Patent No. 5,044,956 to Behensky et al. discloses a system whereby a steering wheel is used to input positions to a simulation which in **[~~turns~~]** **turn** actuates the wheel in response to simulated artifacts. This system does not disclose or anticipate the simulation and coordination of the six-degrees of freedom required for the arbitrary positioning and orientation of solid objects. Similarly, prior art devices which simulate virtual reality by visual feedback to a user are not capable of accepting tactile inputs and providing tactile force feedback.

The paragraph beginning on page 4, line 3 has been amended as follows:

The present invention solves the problems of the prior art by providing a method and system for providing a tactile virtual reality in response to user position and orientation. The present invention further provides a universal device whose kinematics do not replicate any particular device it might control or simulate. A computer mediated control system is provided which transforms forces, torques, displacements, velocities, and accelerations measured by a simulated environment and applies them to the hand controller or **[~~visa~~]** **vice** versa. The present invention can effect and control the superposition of translational displacement with force application and angular displacement with torque, thus providing arbitrary, programmed application of forces, torques,and displacements to the user in any direction.
This allows the device to be controlled by, and to control, external simulations or models as well as physical remote devices. The invention can also locally simulate virtual force fields generated from interaction with virtual surfaces and/or boundaries, can provide software programmed

position, velocity, force, and acceleration limit stops, and can dynamically shift, rotate, or scale these virtual objects.

<u>The paragraph beginning on page 4, line 26 has been amended as follows</u>:

The present invention includes a manipulator for use as a user interface which has a specific joint configuration. This joint configuration yields a design which passively solves the problem of gravity compensation by two constant force springs. Friction in the manipulator is minimized through using a highly back-drivable low gear ratio drive system and high performance brushless DC motors. A general object of the present invention is to provide a tactile virtual reality in response to a **[~~5~~]** user input. According to the present invention, an electric signal is generated for each of a plurality of degrees of freedom of the user as a function of the user position and orientation in three-dimensional space. At least one virtual reality force field is generated in response to the generated signals. A fourth signal is generated for each degree of freedom as a function of the force field, and a tactile force on the user is generated for each force signal.

<u>The paragraph beginning on page 6, line 24 has been amended as follows</u>:

FIGURE 6a presents a top view of the **[~~X portion~~]** **<u>X-portion</u>** of the X-Y table of an embodiment of the manipulator of the present invention;

<u>The paragraph beginning on page 7, line 21 has been amended as follows</u>:

FIGURE 10b presents a side view of the **[~~pitchstage~~]** **<u>pitch-stage</u>** of the manipulator of an embodiment of the present invention;

<u>The paragraph beginning on page 7, line 27 has been amended as follows</u>:

FIGURE 11b presents a top view of the **[~~roll stage~~]** **<u>roll-stage</u>** of the manipulator of an embodiment of the present invention;

The paragraph beginning on page 11, line 9 has been amended as follows:

The kinematic arrangement of the invention is also shown in Figure 5. The manipulator is arranged in a Cartesian coordinate system, and the degrees of freedom are denoted by an X-axis 62, a Y-axis 64, and a Z-axis 66 for translational motions, and a yaw-axis 68, a pitch-axis 70, and a roll-axis 72 for the rotational motions. The axes of these six independent degrees of freedom intersect at a single point which has been located within the handle 52 at a point which is just below where the **[-]** operator's second and third finger/ knuckle rest on the handle. Locating the axes of motion in this way minimizes cross coupling between the degrees of freedom.

The paragraph beginning on page 11, line 21 has been amended as follows:

Referring again **to** Figure 3, the apparatus is attached to a work surface through the baseplate 74. The first two stages mounted up from the baseplate are a simple X-Y table driven by a rack and pinion, and held in place by two parallel rails or linear ways per stage. Because these axes work parallel to gravity, no compensation is required.

The paragraph beginning on page 13, line 14 has been amended as follows:

Referring to Figure 10, the pitch stage is shown. Figure 10a presents a front view of the pitch stage and Figure 10b presents a side view of the pitch stage. The pitch stage is comprised of the pitch motor 160, which is coupled **to** the pitch gearbox 162 affixed to the yaw-pitch bracket 150. The pitch gearbox includes **[~~which contains~~]** a pitch spur gear 166 coupled to the pitch motor pinion 168. The output shaft of the gearbox is affixed normal to the vertical arm of the pitch-roll gimbal bracket 170. The weight of the roll axis and the pitch-roll gimbal is compensated by using a **[~~constantforce~~]** **constant force** spring 172 with a spring spool 174. This does not provide perfect balance **[~~accept~~]** **except** at the equilibrium position. However, the small centering force is easily overpowered by the pitch motor gear train and holding friction.

The paragraph beginning on page 14, line 9 has been amended as follows:

Referring to Figure 12, the handle assembly is shown. Figure 12a presents a front view of the handle assembly and Figure 12b presents a side view of the handle assembly. The handle assembly is attached to the top surface of the hand grip plate 190 **[~~is~~]** **on** the handle or hand grip

52, anatomically formed for either right **[~~of~~]** **or** left hand usage, depending on the application. In addition, the entire hand grip is modular and can be conformed in a variety of sizes to meet the needs of a wide range of user hands.

The paragraph beginning on page 15, line 20 has been amended as follows:

The preferred embodiment of the present invention, uses a computer mediated control system and software driver**.** [~~an~~] **An** arbitrary mapping of position, velocity, acceleration, and force at the remote end (or within the virtual environment) can be presented to the operator (at the handle of the apparatus), and the position, velocity, acceleration, and force sensed at the handle **[~~or~~]** **of** the apparatus can be arbitrarily mapped to an object within a remote or virtual environment[~~)~~]. In the preferred embodiment the computer mediation is performed by a single computer and software driver, however, in other embodiments multiple computers can be used to enhance performance. In some embodiments the forces presented to a user can be generated through the sensing of actual forces from a remote device, through computation by an external model or simulation process, or through local computation with the apparatus control computer. This includes the functionality for presenting virtual force field objects and software programmed limits and stops to the user.

The paragraph beginning on page 20, line 9 has been amended as follows:

If the interrupt routine determines that it is time to run the servo code, it first checks (in the overrun logic) to see if a previous call to the servo routines is still being processed (this is done via interlocking flags). If the last loop has not yet completed, i.e. there are too many commands or controls to **be** executed in the user programmed interrupt call-back period, an overrun is signaled**,** and the new interrupt is rejected until the old one is fully completed**[~~,~~].** **[~~also~~]** **Also,** servo calculations compensate time normalization based on the overrun information -- in effect, when overrun occurs, it is as though the clock interval has been doubled in duration.

The paragraph beginning on page 21, line 22 has been amended as follows:

After starting the interrupt "loop", the foreground also establishes a loop. This loop consists of polling for input from the command serial port and output from the interrupt loop and processing these inputs and outputs if present. If serial input becomes available, it is read and decoded. For

a typical master-slave protocol, the input will consist of slave positions or forces which are transformed from native slave coordinates to scaled master Cartesian coordinates and which are then used to update gains, center locations, or forces in one or more interrupt level servo functions to create a force "feel". The output from the loop will typically be center locations or offsets which are transformed back to slave coordinates and transmitted out of the serial port. Polling of the stick buttons, triggers, panic buttons, **and** power supply level will also normally be performed as well.

The paragraph beginning on page 22, line 29 has been amended as follows:

For cases where D is larger **[~~that~~]** **than** Rmax, the force contribution, Fin and Fout, are [0,0]. For cases where D is less that R, Fout is zero and Fin is computed as a force directed toward the center, Xc, Yc, from the current joint coordinates, X, Y. This computation is as follows:

$$Fin = [X-Xc\ \ Y-Yc] * (-kin*D - velocity*din + Kin).$$

Where velocity is computed from successive D measurements (in turn, computed from successive joint coordinate values, X, and Y, through equation [1] above), kin is the inner radius, R, spring constant, din is the inner radius velocity damping factor, and Kin is the inner radius status force term.

The paragraph beginning on page 25, line 14 has been amended as follows:

It turns out in force reflecting applications that the maximum application of force **[~~is~~]** required **[~~that~~]** often **[~~nor~~]** **is not** necessary for prolonged periods. To a certain degree, such peak performance is only required when first touching the representation of an object, at which point it is common practice to "back off" from it anyway. To improve performance yet manage power, the system may take advantage of the fact that most motors have two ratings. One is a nominal consumption-type rating associated with average current during operation. This rating is also a direct function of the degree of heat dissipated by the motor in a steady-state sense; that is, how much heat the motor windings can endure before they start melting. Most motors also have a peak rating, however, which is much higher, often twice as high as the nominal. This value is related to how much power the unit can handle in an instantaneous sense, despite the amount of heat generated.